Perchlorate Treatment by Enhanced Coagulation, Oxidation, and Membranes

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Objectives

- Investigate enhanced coagulation for ClO_4^- removal
- Investigate ClO_4^- removal in ozone/PEROXONE/GAC systems
- Evaluate the effectiveness of membranes for ClO_4^- reduction

Enhanced Coagulation Study Objectives

- Investigate the feasibility of enhanced coagulation for ClO_4^- removal
- Evaluate the effects of pH on enhanced coagulation for ClO_4^- removal

Experimental Design for Enhanced Coagulation

- Conventional treatment processes
- Chemical Dosages
  - 40 mg/L of Alum, 3 mg/L of polymer, 0.01 mg/L of filter aid
  - 25 mg/L of $FeCl_3$, 3 mg/L of polymer
- pHs at ambient and 6.5

Results from Enhanced Coagulation

Coagulant/ Dose (mg/L)	Filter Aid (mg/L)	Site	pH (unit)	CLO_4^- (μg/L)
$FeCl_3$/25	0	PI FE	8.28 7.24	6 7
$FeCl_3$/25	0	PI FE	8.27 7.05	7 6
Alum/40	0.01	PI FE	8.26 7.33	7 6
Alum/40	0.01	PI FE	8.21 6.65	7 7

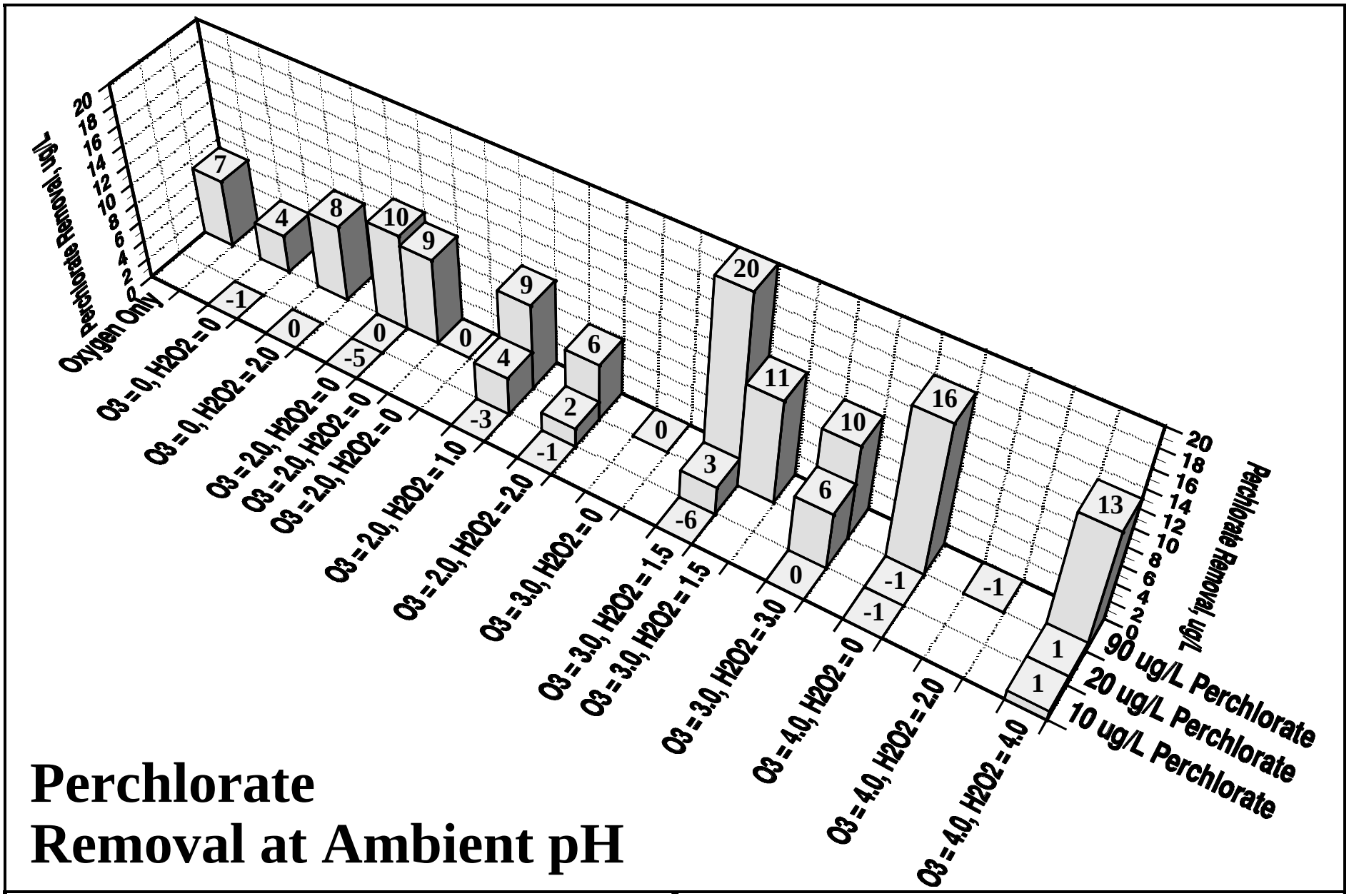
All tests with 3 mg/L of polyDADMAC polymer

Oxidation Study Objectives

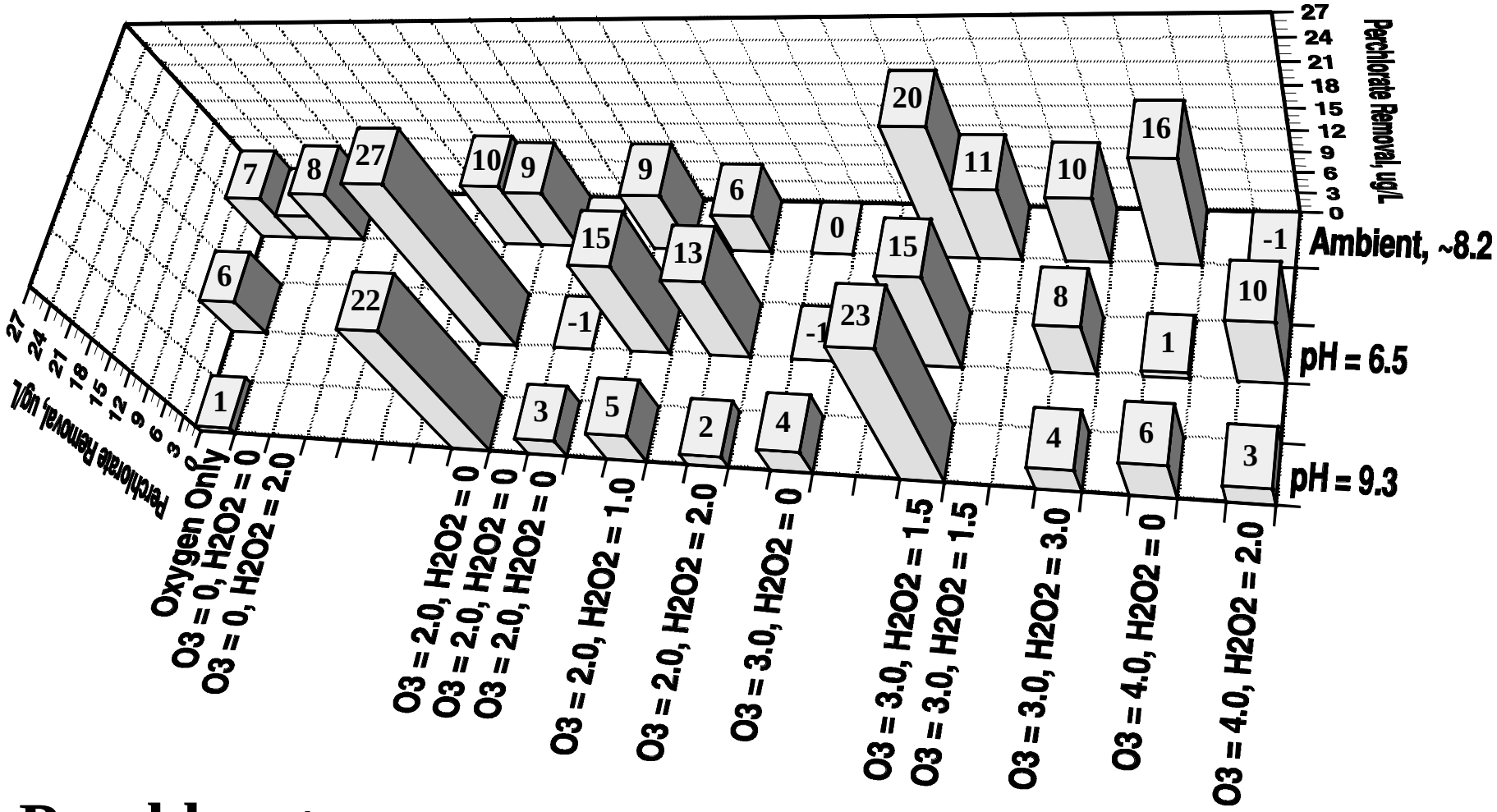
- Determine optimum applied ozone and/or hydrogen peroxide doses for ClO_4^- removal
- Identify the effects of various ClO_4^- levels on ClO_4^- removal
- Evaluate oxidation followed by GAC adsorption for ClO_4^- removal

Experimental Design for Oxidation

- Pilot plant flow of 3 gpm CRW through ozone contactor columns
- Applied ozone doses of 2, 3, and 4 mg/L without H_2O_2 and at 1:0.5 and 1:1 O_3:H_2O_2 ratios
- Spiked ClO_4^- at 10, 20, and 90 μg/L
- Tested ClO_4^- removal at ambient, 6.5, and 9.3 pH



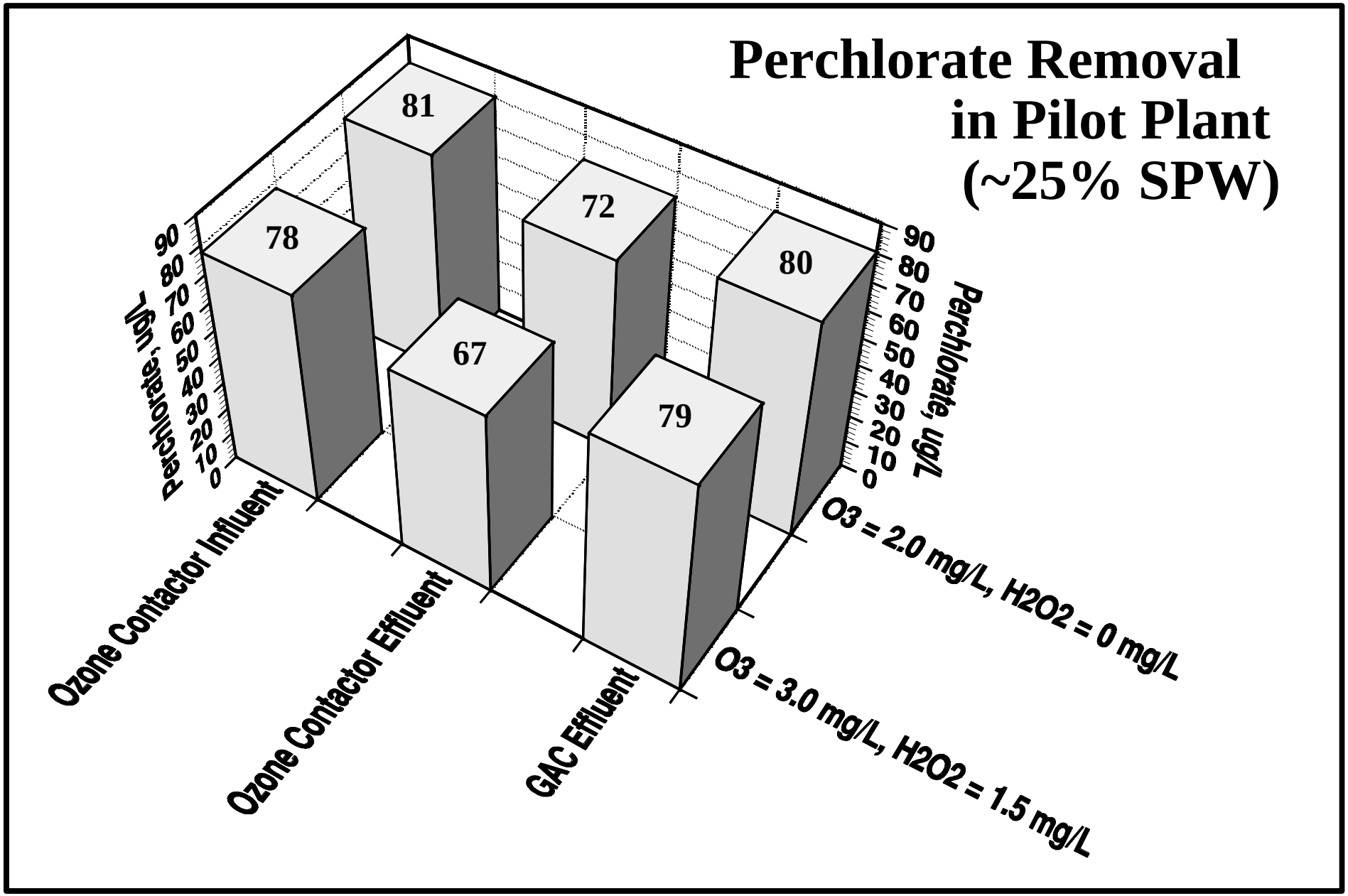
Perchlorate Removal at Ambient pH



Perchlorate
Oxidation at Various pHs (Dose = 90 µg/L ClO4)

Experimental Design for Oxidation/GAC

- Ozone contactor effluent treated in GAC mini column (82 mL/min)
- 2 conditions @ 90 mg/L ClO_4^- dose
  - 2 mg/L Ozone
  - 3 mg/L Ozone: 1.5 mg/L H_2O_2


Perchlorate Removal
in Pilot Plant
(~25% SPW)
Perchlorate, ug/L
0
10
20
30
40
50
60
70
80
90
78
81
67
72
79
80
Ozone Contactor Influent
Ozone Contactor Effluent
GAC Effluent
O3 = 2.0 mg/L, H2O2 = 0 mg/L
O3 = 3.0 mg/L, H2O2 = 1.5 mg/L

Membrane Study Objectives

- Compare ClO_4^- removal using nanofiltration (NF) and reverse osmosis (RO) membranes
- Evaluate the effect of ClO_4^- feed concentration on ClO_4^- rejection rates
- Evaluate the effect of recycling the retentate

Experimental Design for Membranes

- **Spiral Wound Membranes**
  - **Film Tech N70 4040-B (NF)**
  - **Fluid Systems TFC 4820-ULPT (RO)**
- **Post treatment**
- **Spiked ClO_4^- Dosages:**
  - **Low: 20-50 μg/L**
  - **Medium: 500-800 μg/L**
  - **High: 1,000-2,000 μg/L**

Experimental Design (Cont'd)

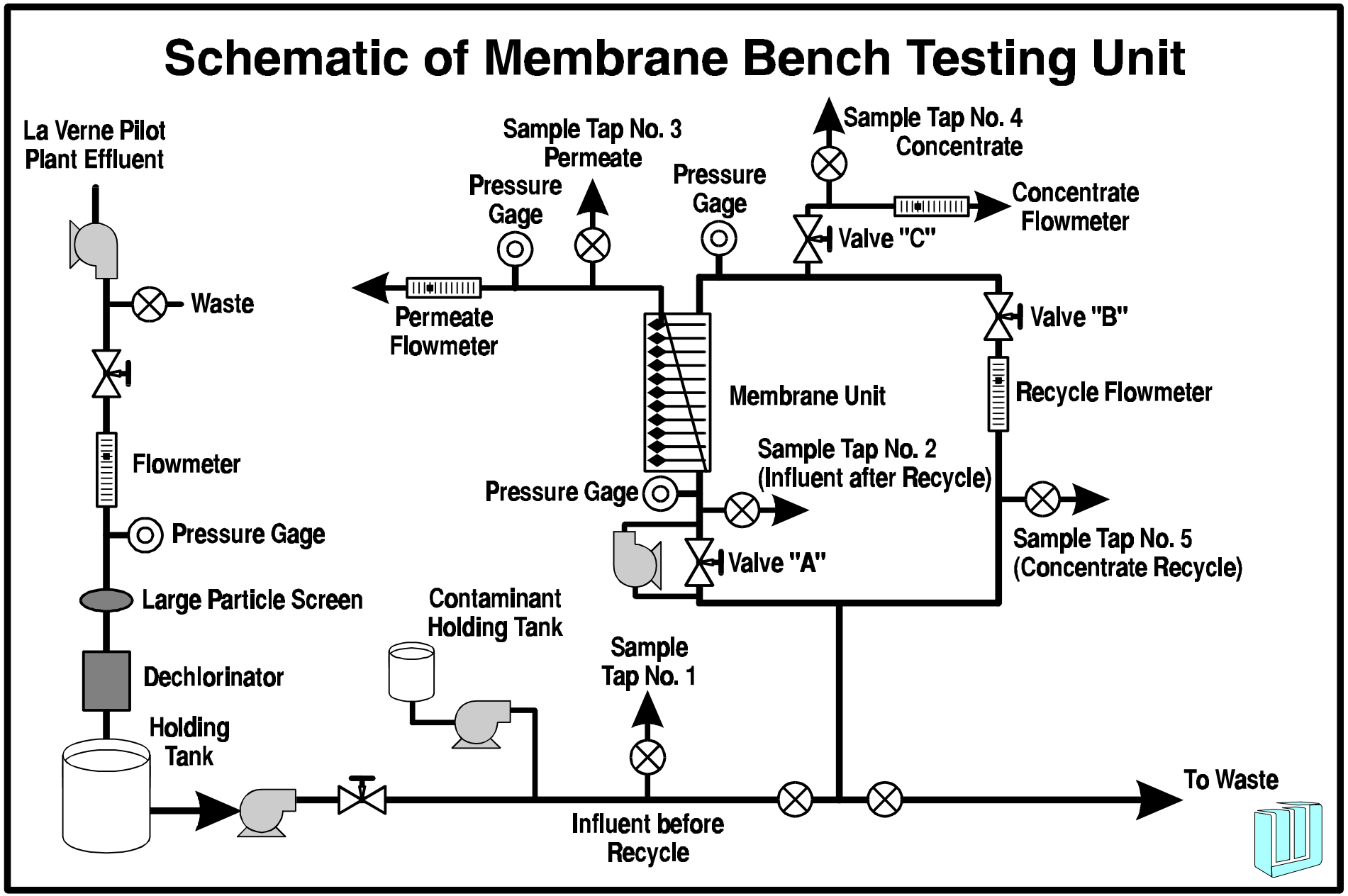
- Brine recycle at 50% of influent flow
- Test duration 3 hours
- Sampled 2nd and 3rd hour at influent, influent with recycle, permeate, and brine
- Measured ClO_4^-, total organic carbon (TOC), conductivity, UV_{254} absorbing organics, turbidity, and particle counts

Membrane Characteristics

Type	MWCO	Surface Charge	Compo-sition	Surface area (ft^2)	Flux (GFD)	Recovery (%)
NF	300 Da	Negative Charge	Thin Film Composite	82	15	20
RO	-----	Negative Charge	Thin Film Composite	72	15	20

MWCO - molecular weight cutoff

Schematic of Membrane Bench Testing Unit



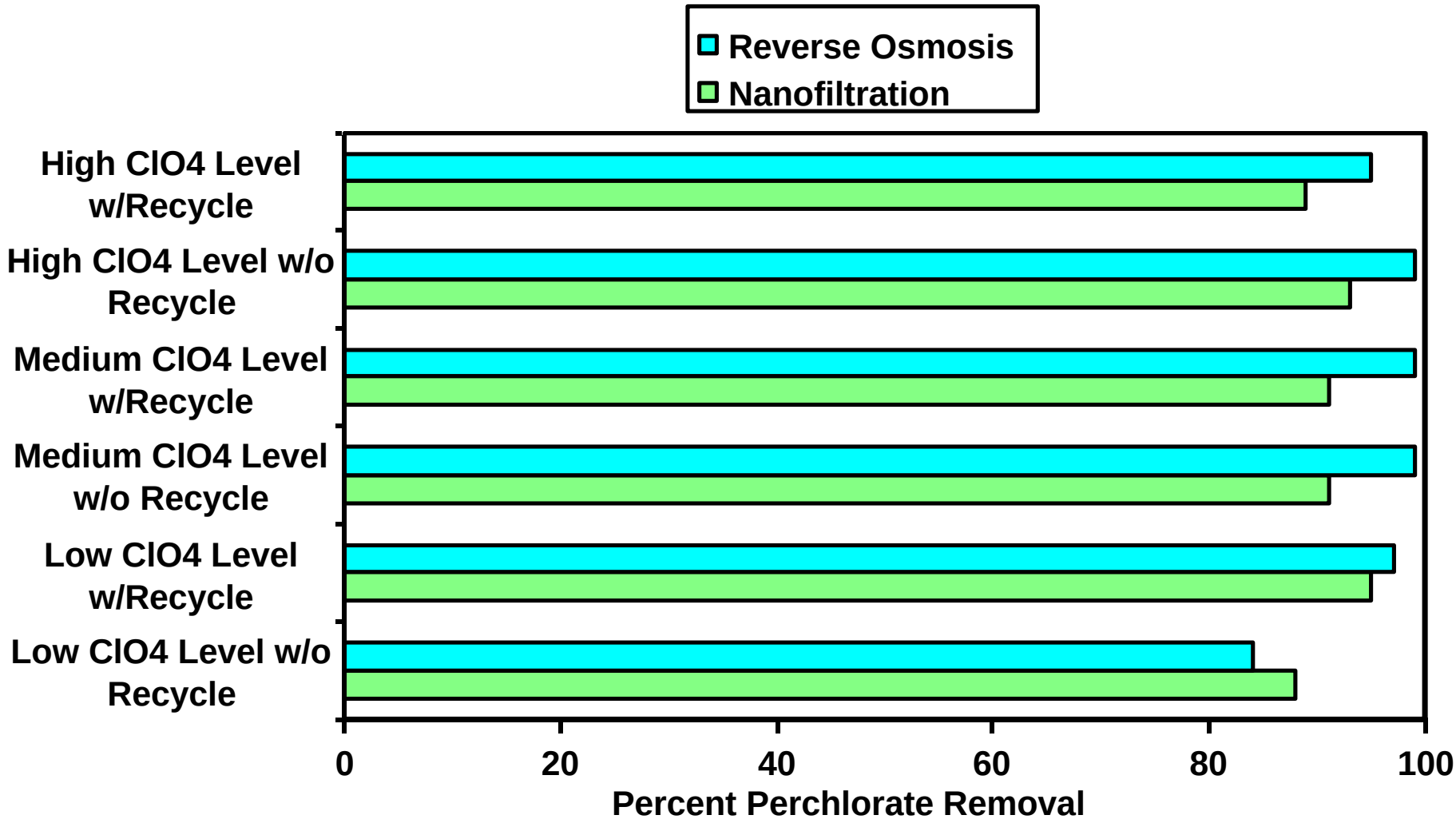
Membrane Influent Water Quality

Source Water	CRW
Total Organic Carbon	2.40 - 3.05 mg/L
UVA_{254}	0.024 - 0.032 abs/cm
Conductivity	969 - 1030 μmhos/cm
Temperature	20.4 - 21.5 ^{o}C
pH	8.09 - 8.24
Turbidity	0.12 - 0.78 NTU
Particle Count	113 - 1590 /mL

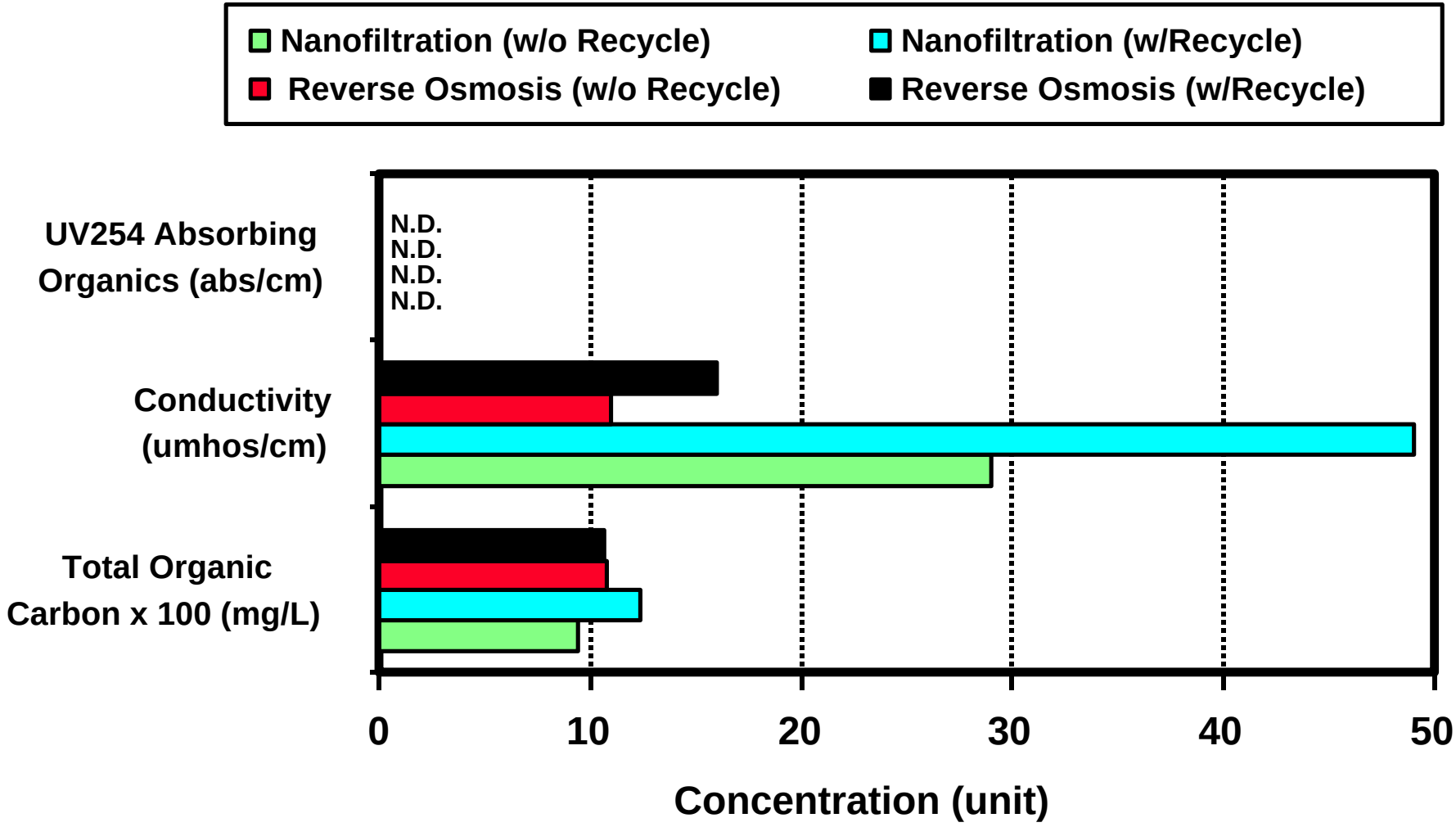
Specific Flux for Membranes

Membrane	Average Pressure (psi)	Average Permeate (gpm)	Average Flux (GFD)	Specific Flux (GFD/psi)
NF	87	0.86	15	0.17
RO	106	0.76	15	0.14

Perchlorate Removal



Permeate Characteristics



Brine Characteristics

- Perchlorate, TOC, conductivity, UV_{254} absorbing organics were concentrated in the brine
- Membrane systems concentrated ClO_4^- in brine by approximately 20-50 percent

Membrane Study Results

- NF and RO membranes can effectively remove ClO_4^- from CRW
- NF and RO performed equally well for ClO_4^- removal at low levels of ClO_4^- and lowered ClO_4^- concentration below 4 μg/L in permeate
- RO performed better than NF for ClO_4^- removal at medium and high levels of perchlorate

Membrane Study Results (Cont'd)

- Brine recycle did not significantly affect ClO_4^- percent rejection, but produced higher ClO_4^- levels in permeate
- Conductivity increased in permeate when brine recycled
- Brine disposal/treatment is required

Conclusions

- **Enhanced coagulation does not appear promising in the treatment of ClO_4^- in CRW**
- **Oxidation does not appear promsing in treating low levels of ClO_4^- (10-20 μg/L); at higher levels (90 μg/L), some ClO_4^- removal may be expected, however results are mixed**

Conclusions (Cont'd)

- Oxidation followed by GAC did not reduce ClO_4^- levels
- NF and RO membranes consistently removed greater than 80 percent of the applied ClO_4^-